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STOPING METHODS AND COSTS IN THE GOLD MINES OF THE BAGUIO DISTRICT, MOUNTAIN PROVINCE, PHILIPPINES

BY

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STOPING METHODS AND COSTS IN THE GOLD MINES OF THE BAGUIO DISTRICT, MOUNTAIN PROVINCE, PHILIPPINES.

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INTRODUCTION

This paper on stoping methods in the Baguio gold mines is the result of a special study made by the authors, under authority of the Philippine Bureau of Mines, and with the full coöperation and assistance of the mining companies in the Baguio gold mining area, to whom acknowledgment is made for much invaluable data. Material for the paper was gathered by the authors during visits to the mines, and from discussions and conferences with the operating heads and their assistants.

Present stoping methods in the Baguio gold mines are evolutionary in that they represent a development from standard stoping practice as used in American mines, such as are found in Butte, Arizona, and the Coeur d'Alenes, to fit special mining conditions in the Philippines. In most cases the American engineers who were placed in charge of development and mining work in the Baguio mines originally endeavored to use the mining methods with which they were most familiar and had used successfully elsewhere. These methods were gradually altered to cope with a different type of ground and to suit a different type of labor, and in many instances have been changed over almost entirely to a new system especially adapted for Philippine mining conditions. That this step has been fully warranted is shown by such indices as reduced stoping cost, increased output per man-shift, larger earnings for mine labor, and by the extremely impressive safety record of the mines.

HISTORY OF THE PRESENT STOPING METHODS IN BAGUIO

The history of the present stoping methods in Baguio is exemplified by the evolution of stoping methods at the Balatoc mine, largest and one of the oldest of the gold mines in the Mountain Province. It is pointed out in a comprehensive paper, prepared by the mine Staff,* that three methods of attack were used originally at the mine, which, in the order of their importance, were (1) square-set stopes, both horizontal and rill type; (2) cut-and-fill stopes with flat back and little or no timbering, or rill type; (3) shrinkage stopes. These methods were more or less standardized and were in use until 1937, when mine production was less than 1,200 tons per day.

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* J. S. Peterson, general superintendent; J. L. Fleming, mine superintendent; H. W. Burton and G. F. Hezzelwood, assistant mine superintendents; R. J. Bonnemort, chief engineer; B. C. Ellsley, geologist.

With an increase in mine production, which reached 2,000 tons per day in 1939, many new stopes were opened, and the experience gained in the early stages of stoping indicated that the methods first used had many disadvantages for the ground. These disadvantages were listed as follows:

1. The great length of stope sections, which is sometimes 100–150 feet and 10 sets wide, caused too much ground to be open for too long a time, giving the walls and back a chance to settle and so requiring heavy timbering and doubling of timber. A large amount of waste was needed to back fill one cut of ore, and the large tonnage handled through fill and ore chutes required much repair to maintain them. This was especially so in rill sections where all ore was pulled through a central chute. There was difficulty in controlling tonnage on account of the length of period required for fill, which in turn, necessitated more stopes to be in operation.

2. In some cases the level interval had been spaced 200 feet, which increased timber and chute maintenance, and in some instances it was necessary to retimber chutes entirely before the stopes were completed.

3. The large stope sections would be out of production for long periods while waste filling.

4. In long stope sections, where splits in the vein occurred, there was difficulty in controlling grade of the ore. If the stope widened, filling was harder. Selective mining and sorting was impossible in rill sections and in long shrinkage stopes. Lack of flexibility in the stoping methods caused trouble in the case of local shearing and breaking of wall rocks.

5. Finally, the long stope sections, with their heavy backs and walls, created unsafe mining conditions and tended to increase the accident hazard. More men were working in the stopes at one time and supervision was more costly.

These conditions were fairly typical where conventional square-set stoping had been attempted in the field, and led to several important changes in stoping practice. These changes included the establishment of the panel system of attack in place of long stope sections, now used with various local modifications all over the field, the inauguration of top slicing where conditions permit, a change in the type of timbering used and a modification of timbering to what is locally called "bastard set" timbering, and establishing a uniform level interval of approximately 100 feet. It should be emphasized that the panel system is very flexible, and, while the general principles used are the same, the method of attack is varied, depending on the character of the ore and the walls, and the width of the ore body to be mined.

ADVANTAGES OF THE PANEL SYSTEM IN BAGUIO

The advantages of the panel system may be summarized briefly as follows:

1. On account of the shorter stope lengths, the mining of the section can proceed faster, and filling is accomplished more rapidly. Timbering is simpler, less attention need be paid to alignment and framing of the members because filling follows almost immediately. As less tonnage is handled through raises there is less maintenance.

2. With shorter stope lengths there is better control of tonnage and grade of ore, as more working places are available in the same mining area. The grade can be regulated by stoping work in sections, as high- or low-grade ore is required.

3. More flexibility is gained, as the short sections can be altered readily to meet any variations in the ore body, and new panels can be changed in type as necessary.

4. Working conditions are safer, as faster mining and filling prevent the walls from settling, and, as fewer men are in the stopes, closer individual supervision is made possible.

5. With higher costs for mine timber, as the supply nearby tends to become depleted, it is highly advantageous to be able to use less timber and smaller sections if possible in the stopes. If long stopes have to remain open, the cost of timbering may be prohibitive. Hence a stoping system that permits quick filling will reduce timber costs and may permit low-grade areas to be worked at a profit, thus extending the life of the mine.

Before describing in detail some of the panel systems used at the principal mines, some general data will be given on timbering practice in the Baguio field.

TIMBER USED IN BAGUIO MINES

In the Baguio mines native pine timber is almost exclusively used. It is easier to handle, is lighter, and lasts longer than lowland timber, and is said to have a greater bending moment.

The timber is obtained locally and costs approximately 65 pesos per M delivered at the mines. Some lowland hardwood timbers of first and second grades are strong and durable, but are too costly and difficult to handle. The third and fourth grades of lowland timbers are very poor for mine use.

At the Baguio Gold Mine some lowland timber, costing 50 pesos per M, is used for stull braces and drift posts. It has not been found suitable for drift caps on account of its small bending moment under vertical pressure. For drift sets, both sawn and round timbers are used at this mine, posts being 10″ x 10″ x 8′, or 12″ round, and caps 10″ x 10″ x 6′, or 12″ round.

At the Demonstration mine round timbers, 6″–8″ in diameter and usually in 5-foot lengths, are purchased from local contractors at 15 pesos per cubic meter, which is a little more than 35 pesos per M. These timbers are cut underground by the miners to fit the ground, using a Japanese saw and adze. Both pine and red or white lauan timbers are used. A drift set of 12″ round timber with 8-foot posts and 6-foot cap will contain about 0.5 cubic meter of timber, and the timber cost on contract would be 7.50 pesos.

Imported Oregon pine for mine timbers has been tried out, and, while superior in strength and durability to Benguet pine, its cost is prohibitive, being about 120 pesos per M delivered in Baguio.

The life of a native pine timber underground is about 2 to 3 years, if the ground is not too heavy. Good ventilation of course is very important in prolonging timber life and hot, stagnant air has a most deteriorating effect.

It is held at several mines that green timber only partially dried out is better than dry timber for heavy ground, as it will not split under pressure. This appears to be directly opposed to a statement by the U. S. Forest Service that "seasoned timber should be used wherever practicable as the strength of green timber is only about one-half that of the same timber when absolutely dry."

Timber is usually framed at the mines with gang saws, but at the Big Wedge mine framing is done by hand, and this is held to be cheaper than by machine. (It may be noted that this mine uses relatively simpler timber framing for the square-sets than some of the other mines.) Sawn timbers are generally used in square-sets, but for the modified square-set, or bastard set, round timbers are often employed at a considerable saving in cost.

SIZE OF TIMBERS

The principal sizes of timbers used in square-sets is 8″ x 8″ for posts and caps, and 6″ x 8″ for girts. Occasionally the ground will permit 6″ x 6″ size to be used.

The standard Balatoc panel set is framed from round timber, with posts 8″ to 10″ in diameter and 6 feet long in the clear (6′ 6″ overall). Caps are of the same size, 5 feet in the clear (5′ 4″ overall). Girts are 6″ x 8″ and 4′ 11″ long.

At Antamok most of the sets have 6-foot posts, but some 5-foot posts are in use in sections of the old mine. This short length is not favored, except for narrow stopes. Chutes and manways are uniformly constructed with 8″ x 8″ timbers, even where 6″ x 6″ are used in the stopes.

At Big Wedge the standard set has 5′ 6″ posts, 5′ cap and 4″ x 6″ girts.

Slabs are used for flooring at all the mines, which when possible are taken up and re-used. The usual size are 2″ x 10″ and 2″ x 12″. For sill floors, 3″ x 12″ is conventional, sometimes with double flooring. Regular shovelling floors are 2″ x 12″, with 2″ chute lining.

Squeeze blocks 6″ x 10″ x 2-ft. are used at the Big Wedge on 10″ x 10″ posts in very heavy ground to preserve the posts and caps, which remain good although the ground movement may curve the blocks almost completely around the posts.

The Balatoc bastard set, or modified square-set, employs more or less standardized timbering in its constructions. (See fig. 18, page 36, for details of this set, also the accompanying discussion.) Caps are 6″ x 6″ or 6″ x 8″, which are supported by posts of the same size which are unframed. Four-inch by 6-inch spreaders are used between sets, and scabs are nailed on the caps as post spreaders. In many cases round poles, 6″ x 8″ on the butt, are used as posts and for set spreaders. The bastard set resembles in some respects the usual stringer set in American mines.

BOARD FEET OF TIMBER PER SET

If a set consists of 1 post, 1 cap, and 1 girt, the standard Balatoc set with members of the size noted above will contain 85 board feet of timber, or about 0.57 board feet per cubic foot of ore, or about 7.6 board feet per ton of ore.

This of course is based on an extension set. The actual timber consumption would be more, as this considers only the members of the set without reference to lagging, wedges, scabs, etc.

A careful compilation has been made by Douglas Strachan, Superintendent of the Big Wedge mine, to determine the timber consumption and cost of mining a block of ore by square-set panels 15 feet long, 4 sets wide, the block being 75 feet long and 102 in height. Such a block would contain 5 panels and 17 floors.

Timber required per floor	Posts.	Caps.	Girts.	Lagging.
Size	8″ x 8″ x 5′ 6″	8″ x 8″ x 5′	8″ x 8″ x 4′ 6″	5′
Number	15	15	12	40
Board feet content	440	400	288	....

Total board feet, 1,128

	Pesos
Cost of timber only at 60 pesos per M	67.68
Cost of slabs for lagging at 25 centavos	10.00
	77.68

Board feet of timber for entire block, 5 panels and 17 floors totals	95,880
	Pesos
Cost at 60 pesos per M	5,752.80
Cost of slabs	850.00
	6,602.80

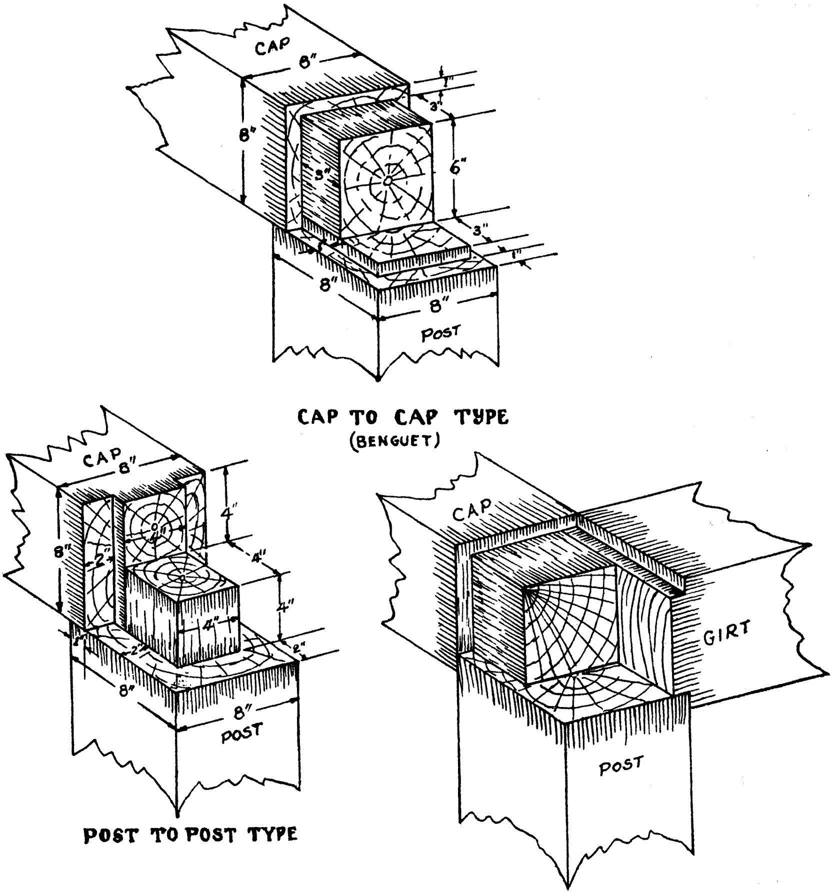
Cubic feet of ore in block	153,000
Tons in block, at 15 cu. ft. per ton	10,200
Board feet of timber per cu. ft. of ore	0.62
Board feet of timber per ton of ore	9.3
Cost of timber per ton of ore, including slabs	0.648

This figure of 9.3 board feet of timber per ton appears to be quite reasonable in comparison with timber consumption in U. S. mines using square-sets. It is stated in I. C. 6691, in the U. S. Bureau of Mines circular devoted to square-set mining, that "from 10 to 30 board feet of timber per ton of ore is required for mining by the square-set method, depending upon the kind of sets used and the weight of ground to be held."

FRAMING OF SQUARE-SETS

Fig. 1 shows three typical examples of timber framing for square-set stopes. Of the three, the cap-to-cap type is favored at most Baguio mines. The construction is so plainly shown in the drawing that further explanation is unnecessary. The cap-butting type in Baguio ground has the advantage of withstanding horizontal ground pressure better than the post-butting type, and it is horizontal pressure rather than vertical that is most generally encountered in this field. It has been pointed out that the horn on the post-butting type has an area of only 16 square inches on an 8″ x 8″ post, and has a tendency to split and spread, and to force the other timber members from their seats.

TYPES OF SQUARE SET FRAMING



CAP TO CAP TYPE
(BENGUET)

POST TO POST TYPE

CAP TO CAP TYPE
(BIG WEDGE)

SCALE $\frac{1}{8}'' = 1''$

FIG. 1.

The Big Wedge set is also a cap-butting type, but the posts are unframed and have no horn. The girts or braces, as they are locally called, have a tenon to hold them in place, whereas the usual cap-butting sets leave the girts unframed.

At the Baguio Gold mine all three members are 8″ x 8″ timbers, including the girts. These latter have 1″ dap on the sides to fit around the caps. This leaves only a 6-inch bearing surface for the shoulder on the post, and does not appear to have any marked advantage over the Benguet type of framing, which employs a 6″ x 8″ girt.

In the bastard or modified square-set at Balatoc the timbers are cut square and are unframed, with spreaders used between sets, and sometimes butt caps to the walls.

DEVELOPMENT WORK

The ore in the Baguio mines occurs in four common types of veins; namely, (1) veins dominantly calcite with a small amount of quartz, (2) veins predominantly calcite and quartz, (3) quartz veins, (4) veins of quartz, pyrite, and chalcopyrite, with a small amount of other sulphides. Texture of the ore varies widely from a soft, highly altered gouge material to a hard massive quartz. Veins vary widely in width from narrow stringers to widths of 40 to 50 feet. Wall rocks consist largely of diorites and andesites. Surface alterations may extend to great depth, affecting both the wall rock and veins. The character of wall rock varies; at some mines both walls may be bad and slab off on exposure to air. Very often the hanging wall has a heavy gouge, locally known as "bullhide gouge," a very descriptive term. At some portions of the Antamok Mine the hanging wall is very soft, creating a very serious dilution problem unless close, careful timbering is used.

Usually the same general plan of development is followed at the mines. The mine may be opened up with adits where the topography permits, and interior shafts may be sunk to work lower levels. It was formerly the usual practice to drift on the veins and to open up the stopes directly from such drifts which served at the same time for haulageways. This practice has been pretty generally abandoned in favor of driving a counterdrift parallel to the vein in the foot wall and using it for the permanent haulageway, with crosscuts over to the vein at regular intervals. This presumes, of course, some knowledge in advance of the strike of the vein and assumes fair persistence along such strike.

The advantage of the counterdrive is that it can be driven generally in hard ground and the great expense of keeping the haulageway open in heavy ground along the vein structure is avoided. It is estimated that at the old Antamok mine thousands of pesos spent for maintenance and repair work could have been saved had this scheme been originally adopted.

At Big Wedge it was decided to run a counterdrift on the tenth level of the Keystone vein after experience in drifting on the vein on the ninth level. The counterdrift on the tenth level is in the foot wall about 40 feet from the vein in comparatively hard andesite and no timber is required. Crosscuts are run to the vein every 60 feet.

At Itogon it was found that driving a counterdrift was cheaper than trying to hold the ground open on the vein for a haulageway. At Antamok Goldfields the foot wall drift on the lower levels is kept about 40 feet from the vein depending on the width of the zone of alteration. Crosscuts are 100 to 200 feet apart, and are driven through the structure and into the hanging wall. (See fig. 14.)

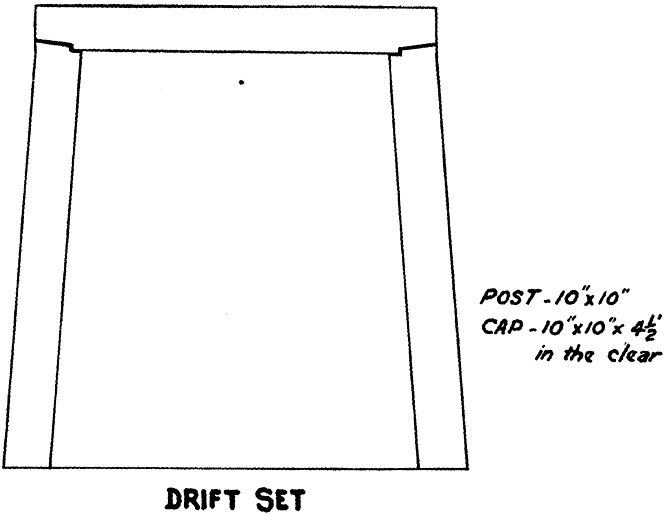


FIG. 2. Drift set at Antamok mine, Benguet Consolidated.

DRIFT SETS

When level development for the panel system consists of drifting on the ore, as at Balatoc, the drift is usually kept in the foot wall. Drift sets are placed with approximately 5 feet spacing. Drift posts are 7½ feet and drift caps 5 feet in the clear, of 10″ x 10″ timbers. Posts are set with a batter of 1″ to the foot. Usually bridge caps on 10″ x 10″ blocks are placed while drifting is in progress. Instead of a bridge cap, pony sets over the drift sets are used at Itogon to take the weight of the fill off the drift set. (See fig. 6.)

At the Antamok mine the members of the drift set are framed as shown in fig. 2. This makes it unnecessary to use a spreader between the posts, which is required when the timbers are not framed. It will be noted that the posts are not beveled to receive the cap, but notched only.

RAISES

Before starting stoping operations one or more raises are driven to the level above, to improve ventilation, to prospect the ground, and to provide in most cases for introducing waste for fill. Raises are driven double compartment with manway and chute. At Antamok Goldfields the raises have been driven at 70-foot intervals to block out stoping intervals, which are timbered with standard square-sets inclined to the angle of the raise. Cribbed raises at other mines are frequently used; they can be put up much faster than a square-set raise. These are 2-compartment raises on 3-foot centers. At Balatoc cribbed raises are driven at approximately 150-foot intervals usually following the foot wall. Three-inch x 12″ x 7′ cribbing with 3″ x 3′–2″ chute and manway, or 4″ x 12″ x 8′ cribbing with 4′ x 3′–6″ chute and manway are the usual size of raises. Occasionally these raises are taken up as short stope sections with stope timbering but this is not common.

DRILLING AND BLASTING

Usually only enough ground is broken at a time to stand a set of timbers. Stope drills are generally used in advancing panels. Detachable bits are not favored. Holes are 4 feet to 5 feet in depth. Jackhammers are sometimes used, and spaders are useful in soft ground. In Demonstration 90 per cent of the drilling in stopes is by hand. Holes may be 3 feet deep, and the ground is drilled and blasted twice for a set of timbers. At this mine it has been found that hand drilling is more satisfactory in the stopes than with machines. The heavy gouge, sticky and wet, carries values, and must be mined. Machine drilling is difficult in such ground.

The ground generally in the Baguio mines breaks well. At Demonstration powder consumption is about 0.48 pound per ton in the stopes. At Balatoc the consumption in the stopes varies from 0.5 to over 1 pound per ton and averages about 0.8 pound per ton. A change in the type of explosives used at Balatoc has decreased the cost per ton.

Consumption of 40 per cent dynamite at Baguio Gold averages 0.7 pound per ton.

HANDLING ORE IN THE STOPES

Using the panel system it is usually possible to shovel ore directly into the chutes where the distance does not exceed 15 feet. Slides are frequently put into sets below the mining floor, and these are moved up as stoping proceeds. Usually only one or two floors are kept open at a time before being filled. An exception is the panel stoping system used at Itogon. (See figs. 6 and 7.)

Where the panel is more than 3 sets wide, wheelbarrows may be used to bring the ore to the chute. At Antamok Goldfields a stope car on tracks is used for wide sections of the vein. The car holds about 600 pounds of ore, equivalent to 3 wheelbarrows. On the lower levels of this mine, where the vein is wide, the chute is carried up about halfway between walls to facilitate shovelling, and is offset as stoping proceeds.

Handling ore by scrapers at the Keystone mine of Benguet Consolidated is described on pages 24 to 26.

ORE CHUTES

Generally the distance between ore chutes depends upon the length of panel.

At Balatoc draw chutes are established and carried up with the stope as a chute and manway. In the square-set panels these raises are square-set raises, in bastard set stopes the last two sets are lagged as chute and manway, and in some stopes cribbed raises are carried. This preparation makes the length of panel normally 25 feet with 5 sets, the last two being used as chute and manway. Where the veins are 8 to 10 sets wide, the panel length is cut down to 3 sets with the chute and manway offset as the stope proceeds up the dip.

At Big Wedge, where panels are 15 feet in length, chutes are placed at either end. With rill stopes, chutes are spaced every 30 to 50 feet.

With the panel system used at Itogon, chutes are never more than 2 sets distant from the panel being mined.

At Antamok Goldfields intermediate raises for fill are usually driven between main raises, which are 70 feet apart. Chutes are 40 feet apart.

On the Keystone vein of Benguet Consolidated chutes may be 25 to 30 feet apart. Cribbed chutes are carried up with the stope, and are offset about 2 sets up.

A detail of chute construction on the Amigo Vein at the Antamok mine is shown in fig. 3. The vein at this point is nar-

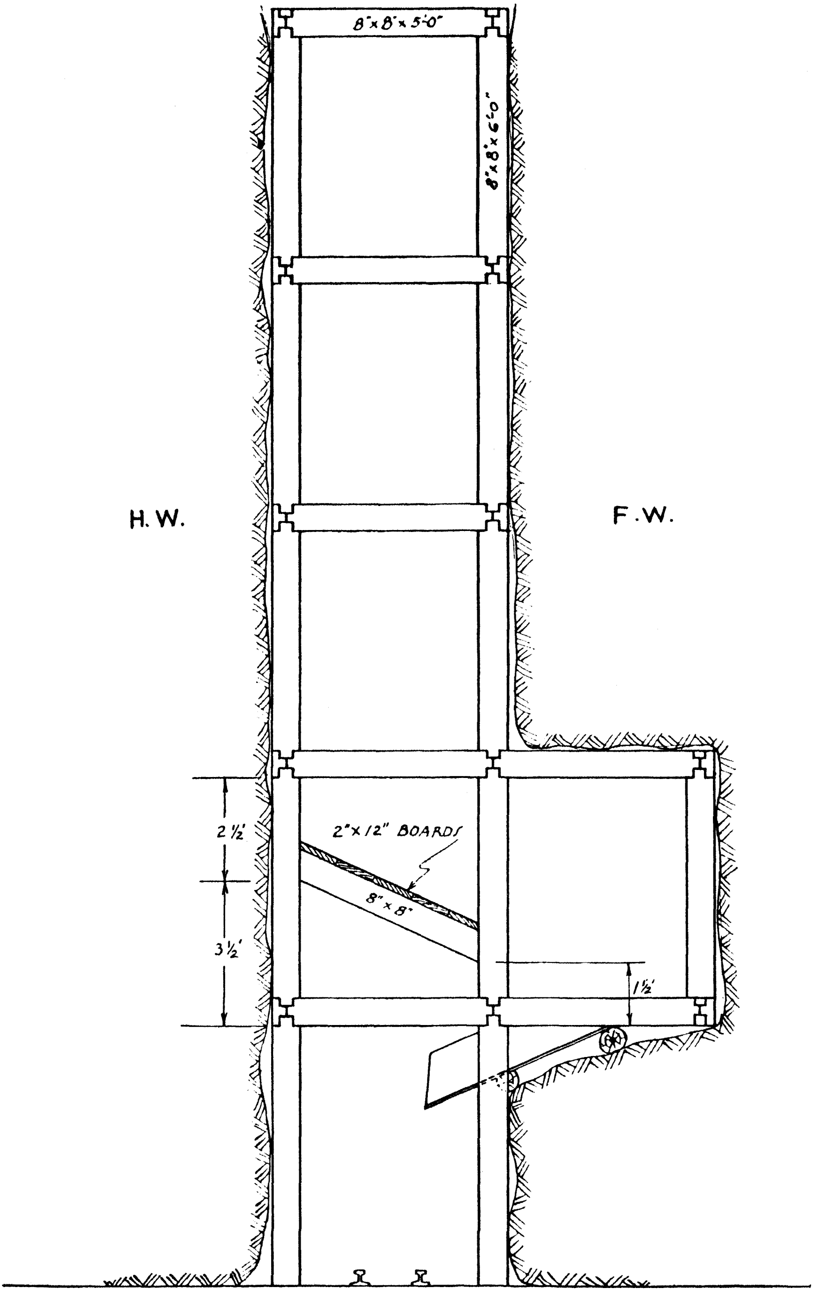
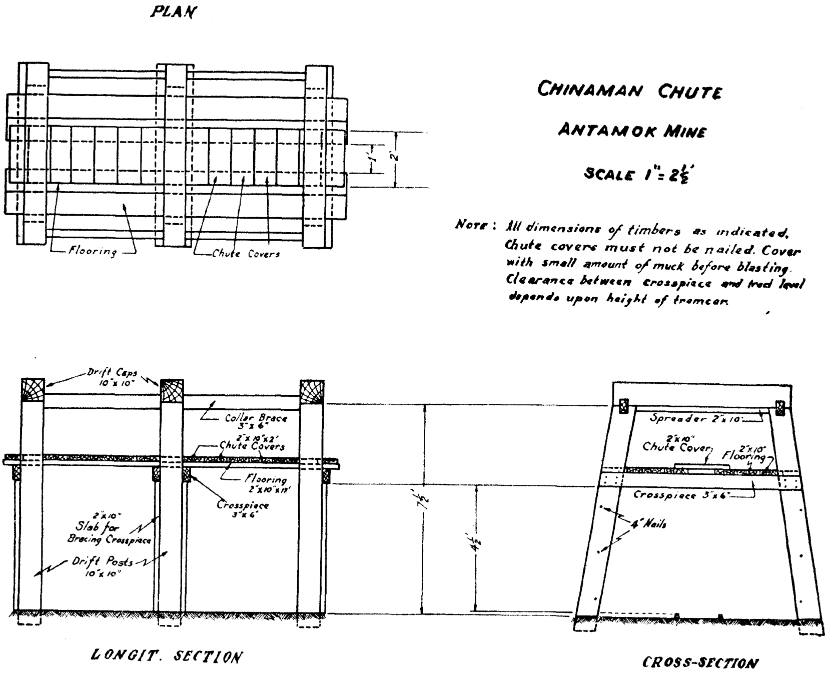


FIG. 3. Details of chute construction.

row and nearly vertical. Ore is deflected in the chute so as to bring it over to a pocket cut in the foot wall and to one side of the track.

CHINAMAN CHUTES

This time-honored device is used in Benguet Consolidated and Balatoc when silling out above the drift sets when the vein is vertical or nearly so, and has proven very satisfactory for the purpose. The construction is plainly shown in fig. 4, which is the type used at Benguet Consolidated. In the construction, 3″ x 6″ crosspieces are secured to the drift posts and sets high enough so that the car can pass underneath with some clearance. Two by 10-inch flooring is nailed to the crosspieces, leaving a central opening exposed which is covered by 2 by 10-inch chute covers and these can be shifted when required by the trammers. The space above the flooring becomes filled with ore after blasting. Cars are run under the chute and chute covers pried away as required to fill the cars.



Note: All dimensions of timbers as indicated. Chute covers must not be nailed. Cover with small amount of muck before blasting. Clearance between crosspiece and tred level depends upon height of tramcar.

FIG. 4. Chinaman chute.

SILL FLOOR PRACTICE

At Balatoc stope preparation consists of silling off on top of the drift bridge caps each side of one of the development raises for a distance of 5 sets in length.

At Big Wedge the sill floor is above the haulage level, on top of the drift.

At Itogon the vein is silled out above the drift set, and pony sets are left open, lagged over with double 3″ slabs when the vein is wide.

At Antamok Goldfields a drift pillar is left over the development drift on the vein, two sets high, and the vein is silled out above the pillar. These pillars are recovered subsequently when mining up from the next level below.

On the Amigo vein at Antamok, when the vein is narrow, the vein is silled out on the haulage level, and the stope is advanced along the vein two sets high. This gives a larger face to break to, and cuts down explosives consumption. (See fig. 5.) The use of Chinaman chutes on narrow veins has already been mentioned.

FILLING

On account of the weak character of the walls in most of the Baguio veins, filling must promptly follow stoping. Seldom are more than two floors allowed to remain open without being filled. Obtaining and distributing fill promptly and economically is a major problem in Baguio stoping practice. The chief sources of filling are from development raises and drifts in waste, from the surface, and from dogholes in the walls.

At Itogon fill is obtained from development waste and from dogholes, The fill settles well and becomes very compact.

At Antamok Goldfields dogholes are driven in the hanging wall for waste. At Demonstration fill is obtained from the surface and from development waste.

Caving raises are driven at Big Wedge, which are fingered out at the top, blasted, and caved.

Dogholes driven in the walls for providing waste are not in favor at either Benguet or Balatoc, as it is held that they weaken the structure and start ground movement.

Concerning Balatoc, the management states:

> Formerly waste filling for stopes was provided largely from development heading and dogholes in the stope walls. This proved to be a very unsatisfactory and expensive supply, especially where large stope sections were to be filled, and as the tonnage increased it became evident that a more adequate and continuous supply of waste should be provided.

Accordingly raises were driven to selected places close to the surface where surface glory holes were started. These raises extended to haulage levels where waste could be drawn into hand trammed or locomotive cars for distribution into the stopes. In one case an offset raise extends from the 1,875 level to the surface at approximately the 1,000 level, with chutes on five levels for distribution.

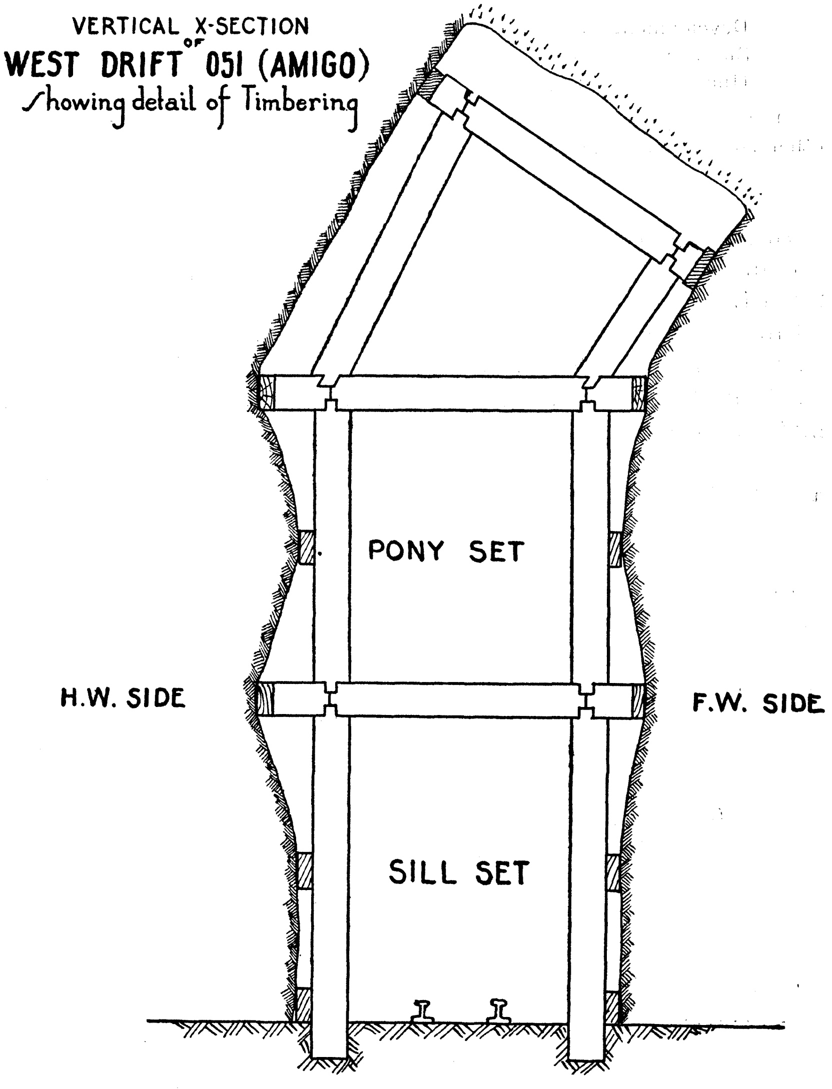


FIG. 5. Stope development on Amigo vein, Antamok.

More recently several underground caves have been started in selected places by driving a series of finger raises above a grizzly chamber ring drilling the finger raises, and blasting the whole area to produce an undercut which subsequently caves itself.

This method has been very successful in some cases, but in others, the undercut has not been adequate and they have failed to cave as expected.

At present it is estimated that the source of waste filling is as follows:

Development headings	per cent	20
Surface glory holes	do	50
Underground glory holes	do	30

Occasionally dogholes are driven for the fill but only when there is no other source available.

SORTING UNDERGROUND

In general there is little attempt to sort the waste from the ore in the stopes. Physical characteristics to distinguish one from the other are generally lacking. At Demonstration about 10 to 12 per cent waste is sorted out, and the same ratio holds at Baguio Gold. The other mines report that the amount of waste sorted out in the stopes is but a small percentage of the material broken, or none at all.

Table 1 gives stoping data at the mines visited in the Baguio area that use square-set methods of mining.

EXAMPLES OF STOPING PRACTICE

Pannel system at Itogon.—At the Itogon mine the former stoping method was to use a flat back cut-and-fill, using standard square-sets. Stopes were usually 50 to 100 feet along the strike of the vein. The present system has been adopted within the last year or so and has proven very satisfactory at this mine. Stoping costs have been reduced about 30 per cent below those under the former system.

Figs. 6 and 7 show the stages in the development and stoping work of the Itogon panel system. The first step is to drive a double compartment raise from level to level consisting of chute and manway. The raise is not cribbed but timbered with standard square-sets.

Stoping starts by silling off on the floor above the drift sets. Pony sets on the drift sets are left open in order to take the weight of the fill off the latter. The pony sets are lagged over with double 3″ slabs. The panels are taken out on one side only, each panel one set wide. Broken ore falls into the chute from a slide, which is moved up as stoping advances.

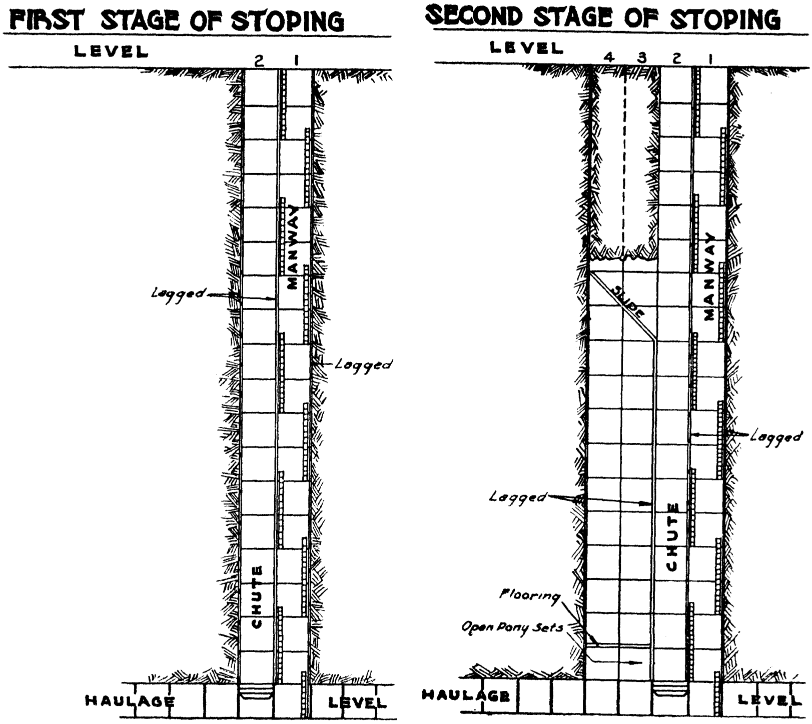


FIG. 6. Itogon panel system.

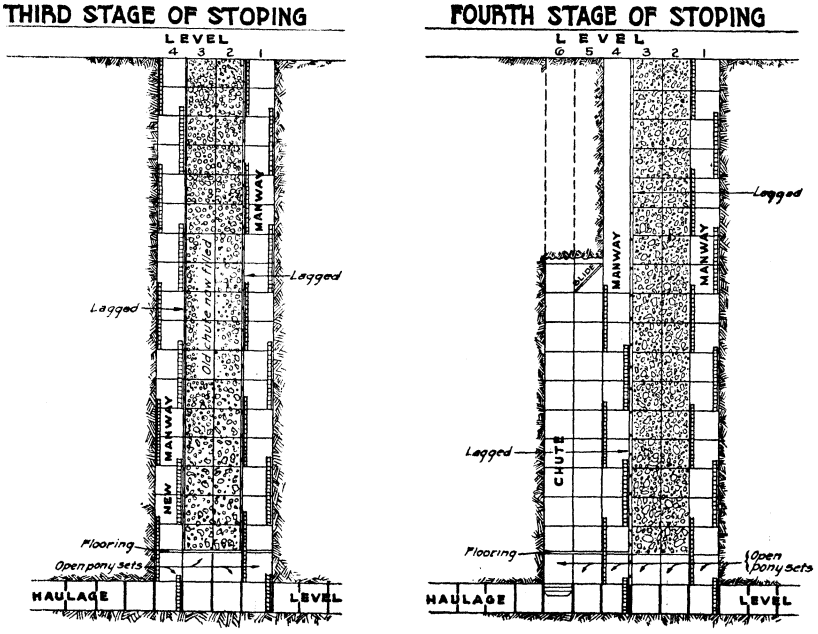


FIG. 7. Itogon panel system.

TABLE 1.—*Stoping data at Baguio gold mines using square-set methods of mining.*

Mine.	Level nterval, vertical distance.	Spacing of chutes under stopes.	Distance between level to level raises.	Position of sill floor.	Size of sets.
	feet	*feet*	*feet*		
Balatoc	100–200	25	150	Above drift bridge caps.	Posts 6′ 6″ } Caps 5′ 6″ } Standard. Girts 4′ 11″ } Also bastard sets.
Benguet Consolidated	100	25–30	[a] 100	Usually above drift sets.	Generally same as Balatoc, but some 5′ sets.
Big Wedge	100	30	100	Above drift sets.	Posts 5′ 6″ Caps 5′ 6″ Girts 4′ 6″
Baguio Gold	100	25	60	Above drift sets.	Principally bastard sets and stull brace sets.
Itogon	85–100	(b)	(c)	Above drift sets.	Posts 6′ 3″ Caps 5′ 6″ Girts 5′ Also bastard sets.
Antamok Goldfields	100	30	70	Above third set. Drift pillar left between sill floor and drift.	Posts 6′ 6″ Caps 5′ 6″ Girts 5′
Demonstration	100	30	60	Above drift sets.	Principally bastard sets and stull brace sets.

[a] Approximate.

[b] Every third set.

[c] See pages 20–21.

Mine.	Method of advance of sections.	Number of floors open at one time.	Horizontal area of section.	Method of handling ore in stopes.	Per cent of waste sorted from ore.	Method of placing filling.	Source of waste for filling.
Balatoc	Horizontal and rill.	2 or 3	Not to exceed 20 square-sets. Full vein width carried.	Shovelling Slides, Rill	10 per cent	Gravity and shovelling.	Underground and surface glory holes and development headings.
Benguet Consolidated	Principally horizontal.	2	Width of vein by maximum of 5 sets.	Shovelling and slides.	Small	Gravity and shovelling.	Development work and surface.
Big Wedge	Horizontal and rill.	2	Width of vein by 30 feet.	Principally rill.	Small	Gravity and shovelling.	Underground glory hole and development work.
Baguio Gold	Horizontal and rill.	([d])	([e])	Shovelling.	10–12 per cent.	Shovelling, some sorting.	Sorting, dogholes, development work.
Itogon	Vertical and rill.	2	Width of vein by 2 sets.	Slides No shovelling	None	Gravity	Development work and dogholes.
Antamok Goldfields	Horizontal and rill.	2	Width of vein by 20–30 feet for wide vein or 40 feet for narrow vein.	Shovelling Wheelbarrows Stope cars Slides.	Small	Shovelling Slides	Dogholes in walls. Development work.
Demonstration	Horizontal and rill.	2	Width of vein by 30 feet.	Shovelling Wheelbarrows	10 per cent	Shovelling	Dogholes. Development work. Surface.

[d] See pages 28–29.

[e] See pages 28–29.

When the panels have broken through to the upper level, the original chute (Panel No. 2) and the next panel (No. 3) are filled from development waste, after lagging the side of No. 3. Panel No. 4 then becomes the new manway.

Two new panels are then started from below as before, Nos. 5 and 6, with No. 6 becoming a chute, and advanced as before. When these have broken through to the upper level, panels Nos. 4 and 5 are filled, No. 6 becomes the new manway, and work proceeds in regular cycle.

The advantage of this system of panel work is that all mucking of ore and fill is eliminated More chutes are required, but it is held that chute construction cost is less than mucking expense. The system is elastic, and can be varied to meet special ground conditions. As only a small horizontal section of stope is open at any one time, there is less immediate necessity to fill promptly, as is required when longer horizontal sections are stoped.

No sorting is possible under this system of panelling, as there is no handling of the ore by the miners.

MINING FLAT VEINS WITH SCRAPERS AT THE KEYSTONE MINE

The vein being mined is a very irregular offshoot of the main Keystone vein varying from 1 to 5 feet in width and from 15° to 45° in dip. On the lower part of the vein the hanging wall is strong enough to permit mining with stulls. On the upper part the hanging wall is loose, requiring square-sets, tightly lagged and it is sometimes necessary to use spiling.

All stoping is done from panel raises, 2 sets wide, which are driven 30 feet apart, center to center, thus leaving a 20-foot pillar between raises. Panels are timbered with 8″ × 8″ standard square-sets, using 2″ lagging.

As soon as the face of the panel is 10 to 15 feet away from the drift, a double drum scraper hoist is installed directly above the chute, in a regular square-set cut out of the hanging wall.

When the panel raise has reached either the extent of the ore body or the next level, a stope is immediately started with 2 panels on either side of the raise.

To start this stope the miners come back a certain number of sets from the top of the raise, usually 4 or 5, depending on the ground, and then work back up to the top, with one pair of miners on each side of the raise. Regular 6″ × 6″ square-sets are used in the stope itself, as it will only be open for a very short time, and the men can always retreat to the 8″ × 8″ raise for safety. Posts are set normal to the dip of the vein.

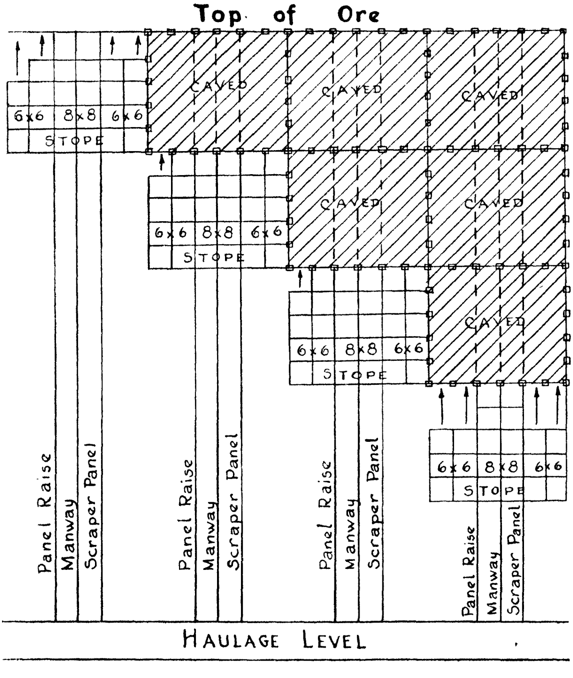
When these 4 stope panels are finished, there is a stope 6 sets long by 4 or 5 sets along the dip. All the inside posts are then drilled with an air auger, the bottom side is slabbed off, and the whole stope is shot down.

The next cut is started, another 4 or 5 sets below the bottom of the first, and the procedure is repeated.

The ore is all hand mucked to the scraper panel, making a mucking distance of from 0 to 10 feet on one side, and 0 to 15 feet on the other.

When the stope is shot down, it removes all weight from the vicinity and the adjoining stope connects to the caved portion practically as if to a solid pillar.

The system when applied to a large area gives a continuous production with no interruption for filling. Stopes are kept



Horizontal plan of a block in operation with the stopes staggered and operating simultaneously.

Stope timbers at sides of stope, not blasted in the process of caving, to minimize breaking of adjacent ground.

FLAT VEIN, KEYSTONE
(DIP 15°-45°)

FIG. 8. Mining flat vein at Keystone vein, Benguet Consolidated.

staggered so as not to open up too large a continuous area of ground. The two panels are drilled and blasted simultaneously. One panel is sometimes kept in advance of the other to avoid caving too much ground. If the ground gets bad, the second panel may be pushed still more ahead. The down side of the panels being mined, the timbers are lagged to prevent dilution into the stope below. Holes are hand drilled when possible to keep the muck dry.

Fig. 8 shows the stoping operation in plan.

Details of scraper installation.—A 19-h.p. double drum scraper hoist is used, with ⅜-inch cable to pull the scraper down, ⅝-inch to pull it up. The scraper is of the hoe type without teeth, made of manganese steel, 30″ across and 20″ high. It requires about 3 scraper loads to fill a 14-cubic-foot car. The distance pulled with the scraper varies from 65 to 235 feet. One scraper can handle 4 panels.

TOP SLICING AT BALATOC

This method of mining has been inaugurated when conditions permit, and at Balatoc it accounts for about 20 percent of the total tonnage mined. It is used for mining areas near the surface where the top of the ore bodies has been developed, and has been proven to be highly successful for re-stoping old portions of the mine that were formerly mined and filled as early as 1932, and where the fill has become so hard and compact as to be distinguished with difficulty from the original ground.

The system is modified to meet any number of conditions but the method of attack is essentially the same. It is applicable for areas with highly altered soft walls, where it is impossible to obtain a supply of waste for filling. It is advantageous for mining surface areas where the vein flattens off and where there is no level above.

The development work for top slicing consists of driving cribbed raises at 40 to 60 feet intervals from the haulage level to the top of the ore, and connecting them by a sublevel which is carried for the full width of the ore by breast stoping. This sublevel is advanced both ways from each raise. The walls are supported by light 6″ × 6″ stulls spaced on an average about 4 feet apart, with the cap cut to the width of the vein and the posts from 6 to 10 feet high which are set on the floor without foot boards. The side is slabbed to prevent waste from caving in. When the floor is clean, stringers are laid parallel to the strike of the vein and covered with slabs laid crosswise. When this is completed, posts and stulls are drilled and loaded with explosives, and all are electrically blasted, causing caving of the back for the entire extent of the sublevel, with a heavy mat of waste rock and broken timber which may be 2 or 3 feet thick. A new horizontal slice is then started below the mat, and advanced as before from both raises, meeting approximately halfway between raises. The long stringers are caught up and supported by posts which rest on the floor of the new drift, and these support the weight of the mat above until room is made for a set of timbers if this is required. Figs. 9 and 10 show longitudinal and cross-section views of top slicing of an old filled area.

In mining, the ore is hand-shovelled when near the chute, but as the distance becomes greater, wheelbarrows are used.

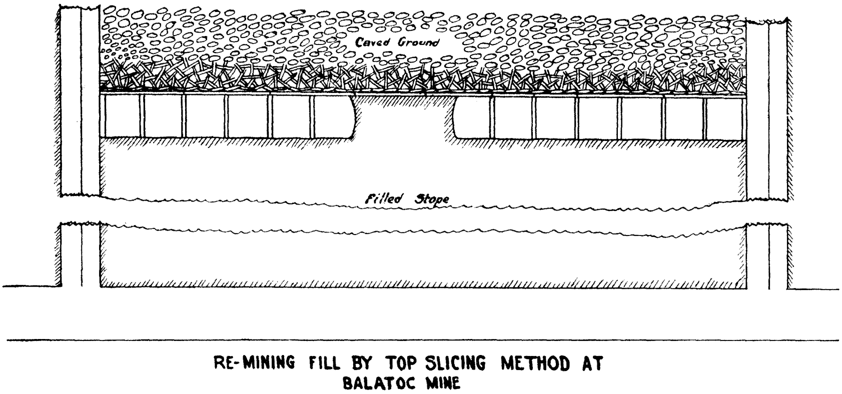


FIG. 9. Top slicing at Balatoc, longitudinal section.

The horizontal slices may be 6 to 10 feet in height, and average about 8 feet. During the rainy season the slices are reduced to 6 feet. As waste is encountered in mining it is sorted out and laid on the slabs on the drift floor. The posts are bored with auger holes about 18 inches above their bottom, so that when blasted only a short butt will project through the mat.

Top slicing requires that the ground above must cave evenly when support is removed in the slice above. Therefore, irregularities in the outline of the walls must be removed before blasting the posts, so that the mat will not be hung up and leave any open spaces. If the vein does not dip steeply, it is difficult to get the mat over to the hanging wall and it may be necessary to drill and shoot a few holes in the hanging wall if there is any doubt about its caving.

The advantages of top slicing are:

1. Stoping is not held up for lack of fill.
2. Ventilation is good.
3. Accident rate is less than under other mining methods.
4. Stoping cost is less than conventional square-setting.

The work is contracted to experienced miners at 7 centavos per cubic foot, but the mine foremen direct the operations and indicate what ground must be carried, their judgment being guided by daily sampling of the ore faces. The contract rate is for labor exclusively, the company furnishing timber, explosives, and supplies.

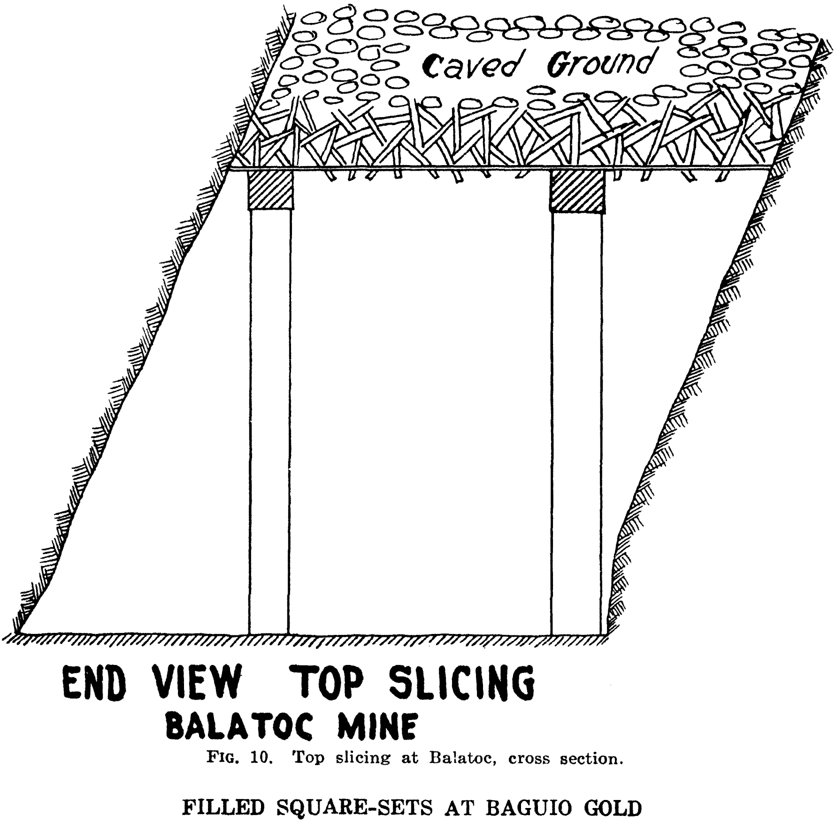


FIG. 10. Top slicing at Balatoc, cross section.

FILLED SQUARE-SETS AT BAGUIO GOLD

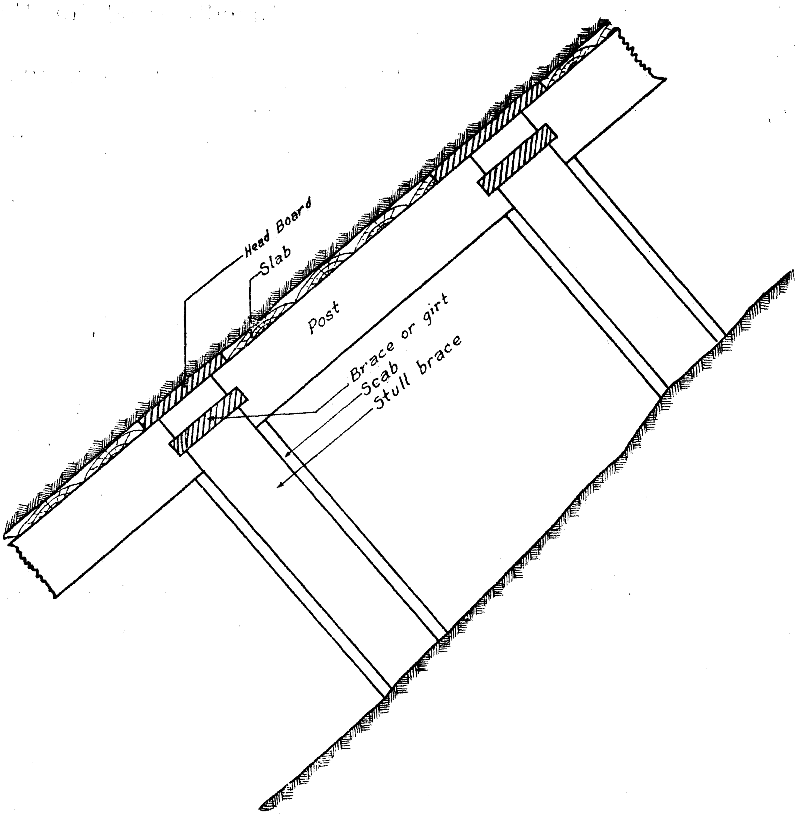
The Joseph vein, one of the main features at this property, is characterized by lenticular ore shoots of widely varying thickness and extent, each ore shoot constituting an individual mining problem. The vein dips at a low angle, averaging about 22°, and the width may vary between 2 to 8 feet. The ore is generally high grade. The hanging wall is exceptionally good for the Baguio field.

The management has mined this vein successfully with filled square-sets, varied to suit local conditions. When the width is narrow, stulls are used, or stull brace sets as they are locally called. No standard panel set is used on account of the vagaries of the ore shoot. The system adapted is extremely elastic and has proven economical for the ground. About 60 per cent of the stoping is by stull brace sets.

In development, cribbed raises are driven from level to level on the foot wall 60 feet apart, and stoping is started immediately above the drift level, with double caps over the drift sets which are floored with slabs. Horizontal flat back stoping proceeds, using stulls or stull brace sets placed normally to the hanging wall to support the back. Stulls are generally about 4 feet long, and are spaced 4 feet apart, but they may be much shorter than this where the vein is narrow. A center chute, single compartment, is carried up with the stope, midway between the development raises, thus reducing the shovelling distance to 15 feet. Filling follows rapidly, and no more than two floors are kept open at any time. Fill is obtained from development work, from dogholes in the walls, and from waste sorted out in stoping.

The stulls may be 6″ × 6″ timber, or even smaller in section. An effort is made to recover the timber for re-use. The cost of timber used in stoping by this method exceeds the labor cost per ton of ore by a small amount. While the consumption of board feet of timber per cubic foot of stope area may be normal, it becomes high based on tons of ore to the chutes, as a certain amount of waste is sorted out and used for fill.

Many sections of the Joseph vein are contracted to experienced miners, on a sort of lease system, which has been tried out over a considerable period, and has proven satisfactory to the company and the contractor. Under this system the contractor takes over a stope and engages his own crew for the job. The stope is sampled daily, and the mine foreman guide the contractor as is necessary. He is paid a minimum rate per ton of ore of a stipulated grade placed in the chute, with a graduated scale upward if this grade is exceeded. As all waste rock is handled on the contractor's own time, he is careful not to overbreak, and to mine clean. The contractor and his men are guaranteed a daily wage, but it is seldom that they must fall back on it.



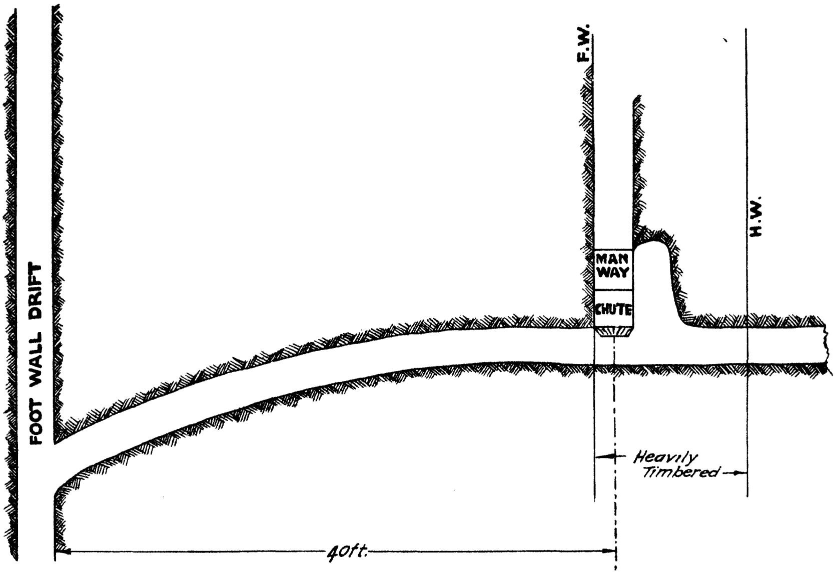
DETAIL
Post—4′ in the clear 8″ × 8″ or **6″** × **6″**
Girt—4′ in the clear 2″ × **10″ or 2″** × 8″
Stull Brace—Height, width of the vein 8″ × **8″ or 6″** × **6″**
Slab to hold back Scale: 1″ = 10′

FIG. 11. Stull brace set at Baguio Gold.

FILLED SQUARE-SET STOPING AT ANTAMOK GOLDFIELDS

On the lower levels of this mine the vein is developed by a counterdrive or foot wall drift with crosscuts over to the vein, which are driven to the foot wall and into the country rock for a short distance to provide room for empty cars, as the chute is located some distance back in the foot wall. A plan of development is shown in fig. 12, and longitudinal and cross section of a stope in figs. 13 and 14.

A drift pillar 2 sets high is left over the crosscut when it cuts the vein in order to decrease maintenance and repair costs due to heavy ground in the drift below the stoping. With careful mining no appreciable amount of ore is lost during recovery of the pillars. This cross-cut is heavily timbered. The pillar is recovered later when mining from the drift below.



PLAN OF DEVELOPMENT FOR STOPE ON ON L-1460
ANTAMOK GOLDFIELDS

FIG. 12. Filled square-sets at Antamok Goldfields, plan.

LONGITUDINAL SECTION OF STOPE ON L-1460
ANTAMOK GOLDFIELDS

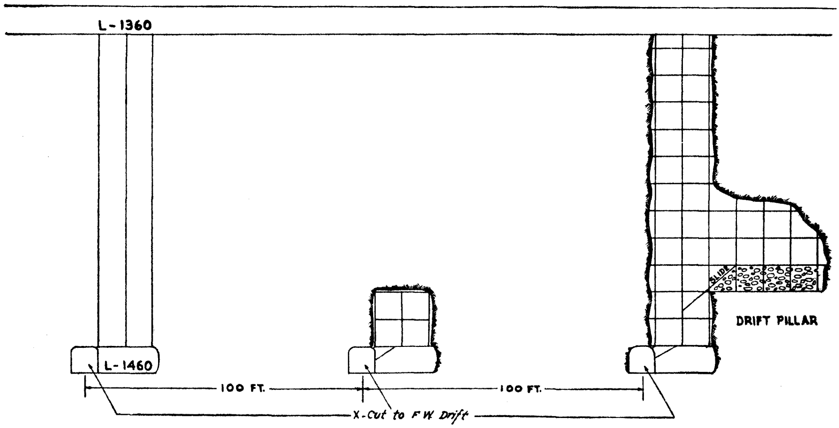


FIG. 13. Filled square-sets at Antamok Goldfields, longitudinal section.

The width of the vein may be as much as 50 feet, averaging about 3 sets wide, with an andesite hanging wall and a diorite footwall. The vein dips about 60°, and the walls stand well. Fill is obtained from the walls and from the level above.

With wide veins transverse stopes are opened for the full width and for a short distance along the strike. After a stope section is opened, intermediate fill raises are usually driven between the main raises. Slides are placed parallel with the vein strike, and ore is brought to the slide by wheelbarrow when the distance is over 15 feet.

CROSS SECTION ON L-1460
ANTAMOK GOLDFIELDS

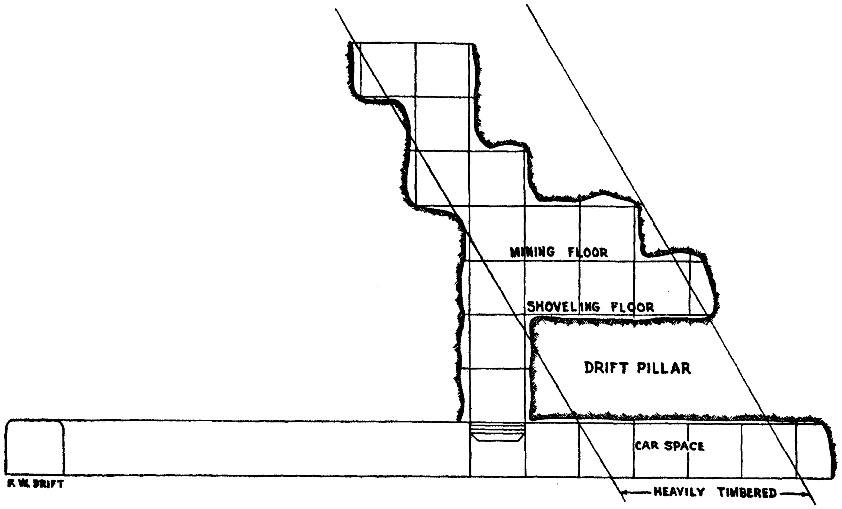


FIG. 14.

RILL STOPING AT BIG WEDGE MINE

On the Keystone lacer vein and on the Broadway vein of this mine a method of cut-and-fill rill stoping is used, which has proven satisfactory. Stopes are from 40 to 60 feet long on narrow veins varying from 1.5 feet to 5 feet in width. The dip is about 60 to 80 degrees. Light stulls, 5″ × 6″, with slabs at either end on the walls, with one or two wedges, provide temporary support until the stope is filled.

Development raises from level to level are driven at 60-foot intervals, and the vein is silled out above the drift sets. An ore chute is carried up with the stope midway between the development raises. Stoping is started on each side of the de-

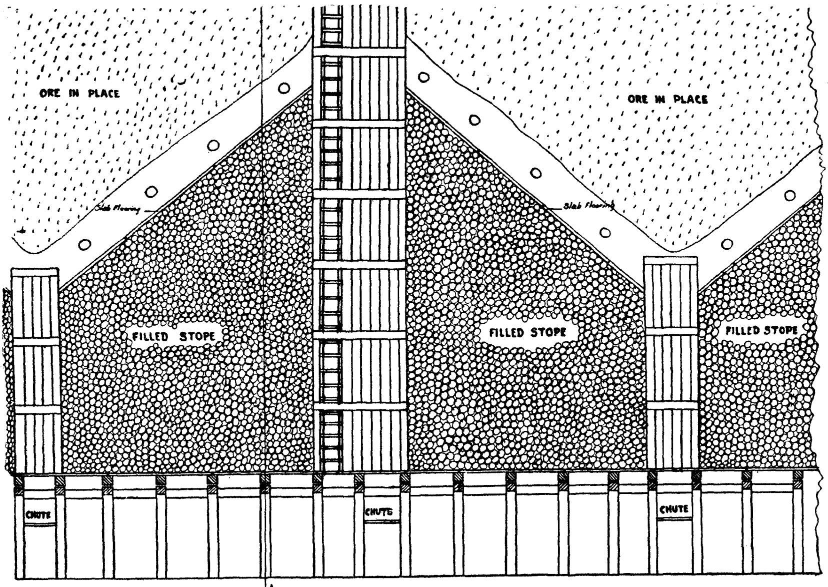
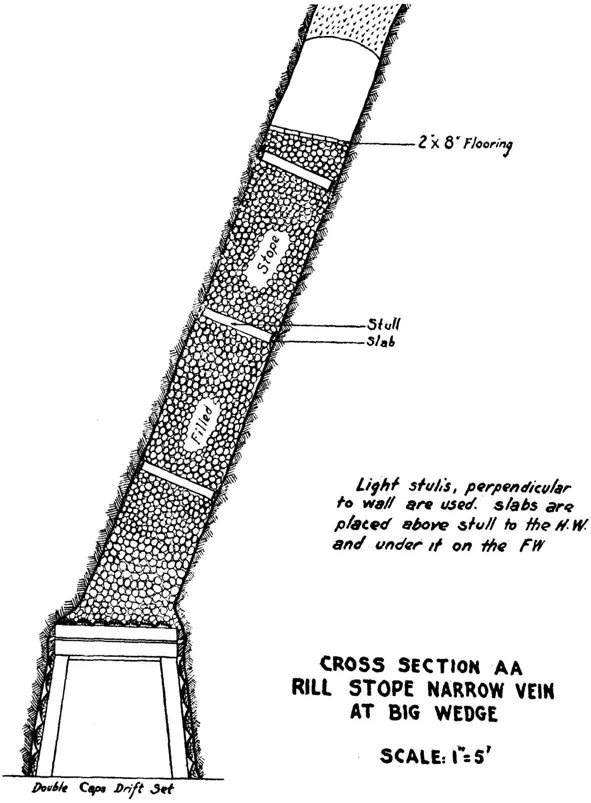


FIG. 15. Rill stoping at Big Wedge, longitudinal section.



Light stulls, perpendicular to wall are used. slabs are placed above stull to the H.W. and under it on the FW

CROSS SECTION AA
RILL STOPE NARROW VEIN
AT BIG WEDGE

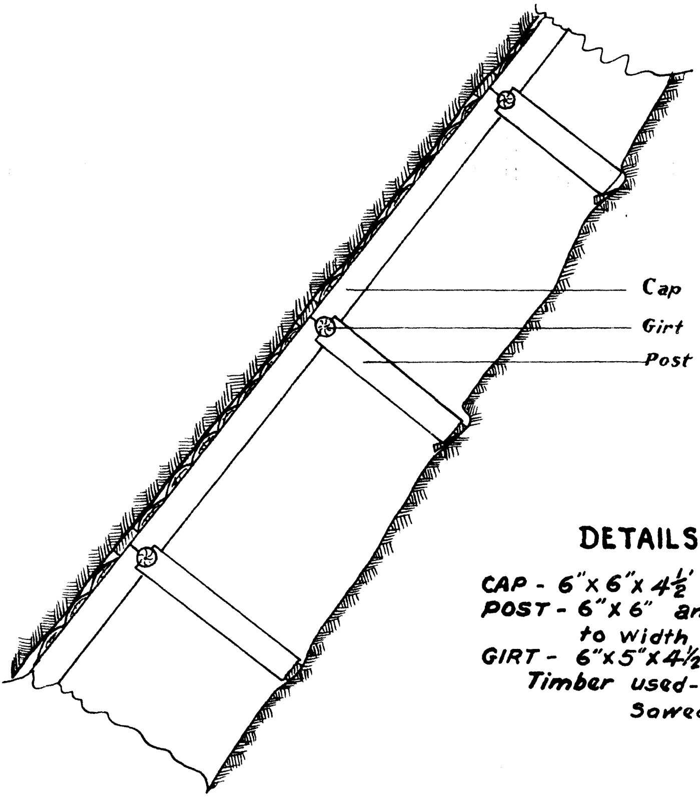
SCALE: 1" = 5'

FIG. 16. Rill stoping at Big Wedge, cross section.

velopment raises, working toward the chute. Ore is shoveled to the chute until the back is high enough so that a rill can be used. Fill is introduced down the development raises, which also serve for manways and for ventilation.

Before blasting, the floor is covered with flooring to keep the ore from dilution with the fill. The flooring is subsequently recovered and re-used.

Fig. 15 shows a longitudinal section on the vein with development raises driven, and the rills started on either side, and fig. 16 shows across section through the vein, with details of stull timbering.



DETAILS

CAP - 6"x 6"x 4½'
POST - 6"x 6" and height to width of vein
GIRT - 6"x 5"x 4½'
Timber used - Round or Sawed

STULL BRACE SET
DEMONSTRATION MINES

SCALE: 1" = 2'

FIG. 17. Stull brace set at Demonstration.

STULL BRACE SET AT DEMONSTRATION MINE

Fig. 17 shows details of a stull brace set at the Demonstration mine. Only the cap pieces are framed outside; all other timbers are cut in the stopes to fit the ground. A hitch is cut in the foot wall to take the stulls or posts; these are tightly wedged as shown. The back is lagged with slabs.

MODIFIED SQUARE-SETS (BASTARD SETS)

As the local name suggests, the bastard square-set is not a conventional set, but a timber set that is cut to fit the ground, rather than cutting the ground to fit the timber. There are several variations of the bastard set.

Itogon.—At this mine a bastard set indicates any set that is cut to fit the ground. Usually the posts are of standard length but caps are cut to the width of the ground opening. The timbers may be either round or sawn, with diameter depending on the weight of the ground. The lower set may have posts on hanging wall and footwall, while the next set may have only a hanging wall post with a hitch cut in the footwall to hold the cap.

Balatoc.—Referring to fig. 18, it will be noticed that the timbers are not framed for the bastard set. At this mine bastard-set timbering has been altered and modified by experience until a more or less standard method is now in use. Bastard sets are commonly used in stoping veins that are less than two square sets wide, where the vein is narrow and irregular, and the walls require timber and filling for support. About 37 per cent of the entire tonnage in the mine is recovered by bastard square sets.

Using this method of mining, the stope is started from the raise above the drift and advanced by breast stoping. Broken ore is recovered through a Chinaman chute until the first floor is mined out, when the floor is covered with slabs and the second floor is started. When the second and third floors are stoped, the first floor is filled and the fourth floor is started. The panel is usually 5 sets long, and the fifth set is made into a manway, which is later converted into a chute when the second panel is started. This is protected from fill by slabbing.

Timbers for the bastard set consist of 6″ × 6″ posts, 6½ feet long, with a 6″ × 8″ cap cut for the width of the vein. The cap is of larger dimensions than the posts, as side pressure is greater than vertical in this instance, and is tightly wedged to

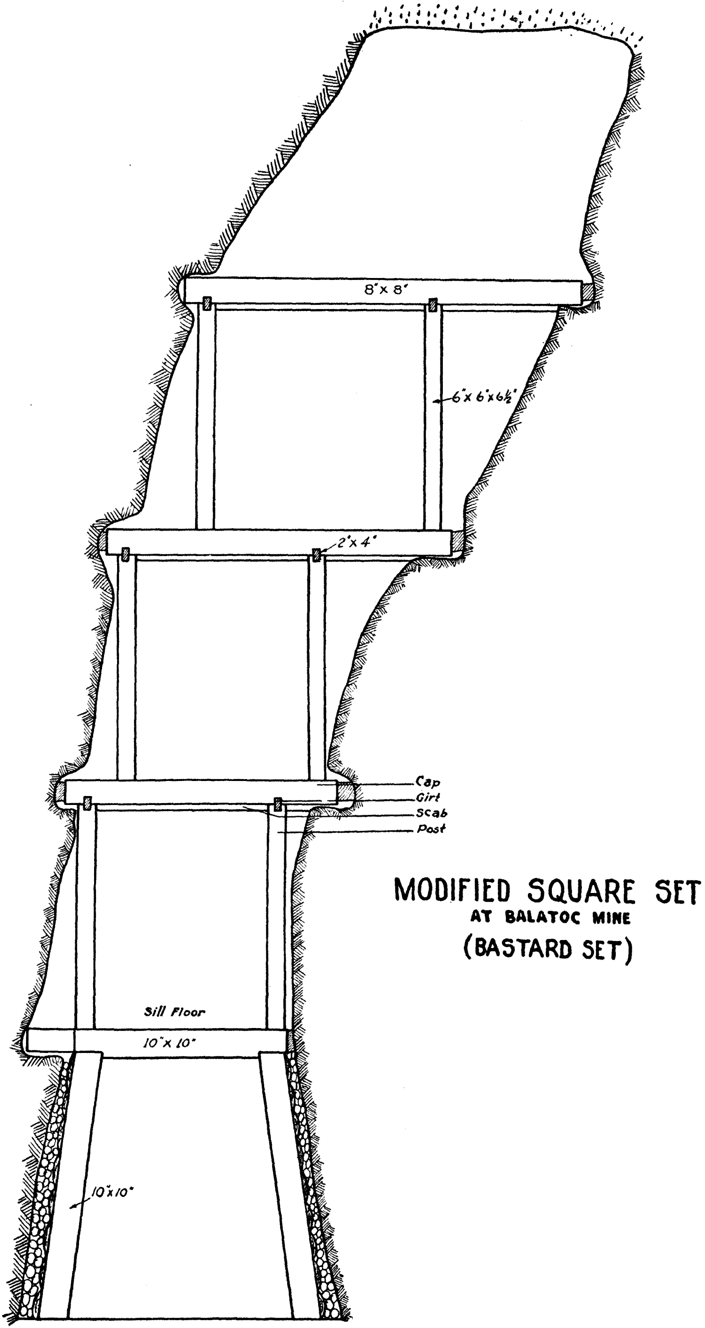


FIG. 18. Bastard set (modified square-set) at Balatoc.

the walls. Posts, which are unframed, are held in place by a 4″ × 6″ spreader and brace or girt. When the cap is long, two posts are used with an inclined post supporting the hanging-wall lagging and a similar post along the foot wall. Slabs 6 feet long are used as side and back lagging, with flat slabs as floor boards. In many cases round poles 6″ × 8″ on the butt are used as posts and for spreaders. It is believed that this system of timbering is original with the Balatoc mine.

STOPING COSTS

It is obvious that comparison of stoping costs may be misleading unless all the items entering into the cost are considered and included in each instance. Thus one mine may include stope preparation and development in its stoping cost, while another may charge all or part to capital cost. Or one mine may charge the cost of air to general expenses, while another may prorate the cost to the stopes.

For this reason no attempt is made in this paper to present comparative stoping costs at each mine. Some instances of cost are presented, however, with the permission of the managements, and every effort has been made to bring out all the items of expense that have been included in the final cost figure, but it does not follow that they are necessarily comparable.

Some general comments on stoping costs may be made. The attitude of the company executives in the Baguio field varies toward contract work in the stopes. In the Benguet Consolidated mines about 100 per cent of stoping is on contract, but at Itogon no stopes are contracted. At Antamok Goldfields there are set prices for piece work, such as mining, mucking, filling, and timbering a square-set. At Demonstration the stopes are contracted. Every panel has a contractor, who has his own crew. Contract rates per car of ore are based on the width of the vein and other mining conditions. The contract rate includes stoping, mucking, tramming, and transfer to the main ore pass.

At Balatoc all stoping work is contracted, and paid for not by the ton or car of ore broken, but on the basis of per cubic foot of ground broken. The rate which varies from 5 to 8 centavos per cubic foot includes all labor for breaking, mucking, and filling. The company delivers the fill to the contractor who distributes it in the stope. All payments are made on engineer's measurements of the stopes, and this eliminates the need to keep accurate count of cars from the stope chutes. The contract figure varies with the condition of the stope and the amount of timbering required. It is estimated that contractors make about 25 per cent more than the day's pay. Individual contractors engage their own men, who share with the contractor in the final payment.

At Big Wedge no work is contracted, but a bonus is paid for the advance in drifts, crosscuts, and shafts when the advance exceeds a set minimum. For instance, a certain standard is set per manshift based on a certain minimum advance per month with a bonus per foot to be paid for any advance in excess of the standard.

An example may be cited through the courtesy of the management which is based on actual figures. A standard of 0.5 foot per man-shift is set which is based on a minimum advance of 450 feet per month, and a bonus of one peso per foot is paid for any advance in excess of this standard.

For the fifteen-day period ending September 30, 1940, a total advance of 341 feet was made, an average of 22.7 feet per day. The standard advance for this period should have been 213.5 feet, hence there was an advance of 127.5 feet in excess of the standard. The labor payment was, therefore—

	Pesos
Labor cost (427 man-shift at 1.53 pesos)	653.05
Bonus	127.50
	780.55

SEGREGATED COST

	Pesos	Cost per foot. *Pesos*
Labor	780.55	2.290
Explosives	1,161.71	3.406
Timber	20.61	0.060
	1,962.87	5.756

The tunnel was driven through medium hard andesite. The contracting crew, on 3 shifts, included 26 men. Total earnings per man were 1.83 pesos per shift.

This system of payment means a lower cost per foot of advance for the company as well as a bigger monthly check to each man on the contracting crew. It is obviously to the contractor's advantage to work with as few men as possible in order to increase the amount of the bonus.

EXAMPLES OF STOPING COSTS

Demonstration.—Certain stopes are contracted on a per-car basis, which contains 0.7 ton, or 14 cubic feet. The contract rate varies from 50 to 75 centavos per car (0.71 to 1.07 pesos per ton) depending on the width of the vein. The contractor supplies all labor for mining, mucking, timbering, tramming, and placing ore in the transfer chute.

Big Wedge.—All regular mine development is charged against stoping cost, including stope preparation, raising, and everything but capital development. The following costs were reported for September, 1940. They do not include cost for pumping, hoisting, haulage, track and pipe work, mechanics, supervision, or supplies other than timber and explosives.

All stopes.	Per ton. *Pesos*
Labor	1.59
Timber	0.55
Explosives	0.28
Total	2.42

Keystone stopes only:	Per ton. *Pesos*	Per cent of total cost.
Labor	1.41	54
Timber	0.60	23
Explosives	0.59	23
Total	2.60	100

The stoping costs are based on 5,011 tons delivered to the mill during this period. There was a daily average of 170 man shifts devoted to stoping, or 5,114 manshifts for the month, thus tons per man shift was 0.98.

Balatoc.—The stoping costs for October, 1940, were given by the management as follows. During the period 2,461 tons per day were mined.

Item	Per ton. *Pesos*
Labor	0.89
Powder	0.24
Timber	0.69
Total	1.82

Average tons per man shift, stopes, 1.74.

The total mining cost during 1939 was 5.085 pesos per ton. This cost includes all items, such as direct stoping, ore delivery maintenance, mine general and operating development, but they do not include capital development. During this period 676,564 tons were milled.

Included in this cost of 5.085 pesos is the cost of explosives amounting to 0.366 peso per ton and the cost of timber amounting to 1.23 pesos per ton.

Baguio Gold.—Average stoping costs per ton for the first 10 months of 1940 are given by the management as follows:

Item	Per ton. *Pesos*
Direct costs of labor	0.72
Direct costs of supplies	0.98
Indirect costs	1.65
General overhead	0.47
Total	3.82

These figures are based on an average tonnage stoped per month of 9,655 tons, and would be slightly lower if tons milled were used instead of tons stoped.

In a comprehensive memorandum on the general subject of accounting and cost keeping at this mine, Mr. W. T. Graham, general superintendent, writes as follows:

> At our property, raises are run between levels through the ore-shoot at about 75-foot intervals, depending on conditions. These raises are carried as a development expense and I believe their purpose justified this method of accounting. They are later used as stope entrances.
>
> All other work pertaining to a given stope or block of ground such as silling-out, filling (from whatever source), and ordinary mining of the ore is considered as a charge against the tons stoped per month.
>
> When using development waste for stope fill, as is done wherever feasible, only the cost of handling this fill into the stope and subsequent distribution in the stopes is charged to stoping.
>
> Where this method of obtaining stope fill is impracticable, we run dog-holes into the hanging wall to obtain fill. This is also charged to stoping.
>
> My system of keeping cost breaks expense down into Direct (labor and supplies), Indirect, and General Overhead.
>
> Our cost sheet reflects all charges which can rightfully be charged to stoping and includes all indirect charges such as ventilation, general maintenance, supervision, compressed air, drill steel, miners lights, bodega cost, etc., etc.
>
> These indirect charges are prorated to stoping, exploration, and development on the basis, generally, of total Direct Charges against a given working place. In this manner each stope bears its proportional charge of all indirect charges in addition to Direct Charges and General Overhead.

General Overhead which includes Taxes (except Income Tax), General Office expense, Manila Office, and all administration charges, is distributed in much the same way as the Indirect Charges.

By my method of distribution all costs of operation and all expenditures, except those for Income Tax, are reflected in the cost per ton. There are no hidden costs to be accounted for, except Income Tax as noted, and when a cost per ton for stoping is arrived at there is nothing to be added.

Itogon.—Based on operations during the first ten months of 1940, during which period 243,305 tons were stoped, the total stoping cost was 2.82 pesos per ton. The following tabulation gives details of the cost, according to data furnished by Mr. Ralph W. Crosby, general superintendent of northern operations for Marsman & Company.

	Per ton. *Pesos*
Direct costs:	
Labor	0.52
Supplies	0.88
Supervision	0.09
Total direct costs	1.49
Distributive costs:	
Power	0.19
Assaying	0.08
Engineering	0.02
Mine distributive:	
a. Underground general	0.23
b. Machine drilling	0.21
c. Timber preparation	0.06
d. Tramming	0.31
e. Hoisting	0.11
f. Pumping	0.01
g. Ventilation	0.01
h. Mine tools	0.01
i. Supervision	0.09
Total distributive	1.33
Total stoping cost	2.82

Tons per man-shift, stoping, 2.8.

Mr. Crosby advises as follows regarding the accounting and cost-keeping procedure for this property:

In our accounting system, the cost of mining is divided into three parts; namely, operating development, stoping and mine department general expense.

To operating development, we charge the cost of all raises, dog-holes and miscellaneous development work. Standard drifts, crosscuts, winzes.

shafts and permanent ventilation raises and diamond drilling are charged to capital account and consequently, are not included in the mining cost.

Stoping includes actual stoping operations, including the driving of dog-holes for fill where same is necessary and also includes all stope preparation work.

The mine department general expense consists of all underground repair work and underground miscellaneous expenditures.

Under direct charges are included the cost of all labor and supplies directly used in operating development headings, in stopes and for the mine department general expenses. The supervision charges against these accounts are a proportion of our total supervision.

Under distributive costs, the cost of power includes a proportion of all power used for underground purposes. This includes power for compressed air, hoisting, ventilation, pumping, locomotive haulage and lights. The cost of assaying includes the actual cost of all assays performed for operating development and stoping operations. The cost of engineering includes a proportion of the total cost of engineering.

The mine distributive charges are subdivided as shown in the attached list. The sub-account, underground general, includes all labor and supply charges for general capataces, sampling, carbide and lamps, miscellaneous maintenance of light and power lines, operation of underground tool bodegas and maintenance of mine telephone system.

Sub-account machine drilling includes all labor and supplies used in connection with mine blacksmithing, drill steel sharpening, compressor maintenance, air drill maintenance, air drill lubrication, maintenance of air and water lines, air and water drill hoses and fittings, new drill steel.

The costs given in the attached tabulation cover all our expenditures for mining with the exception of air and water pipe, mine rails, new pneumatic air tools, which items we charge to capital account. The annual expenditures for these amounts to approximately ₱50,000 of which a considerable portion must, of course, be considered as required by capital development operations. I would estimate that the proportion of these expenditures which rightfully belongs to mine operations should not exceed ₱20,000 per year or approximately ₱0.07 per ton.

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